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EFFECTS OF BROOM RUSTS ON SPRUCE AND FIR

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DIVISION OF FOREST DISEASE AND
TIMBER MANAGEMENT RESEARCH

INTERMOUNTAIN FOREST & RANGE EXPERIMENT STATION
FOREST SERVICE
U. S. DEPARTMENT OF AGRICULTURE
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EFFECTS OF BROOM RUSTS ON SPRUCE AND FIR

Roger S. Peterson [1]

"How significant is broom rust damage?" is a common question among western foresters who work with spruce and fir. This paper reviews the evidence and reports new data.

Broom rusts attack most species of spruce and fir throughout North America, but are particularly abundant in the West. Their most conspicuous symptoms are branch proliferations called witches'-brooms, which produce annual crops of yellow needles. Other symptoms are branch and trunk swellings and cankers. Broom rust of spruce is caused by Chrysomyxa arctostaphyli, a fungus that completes its life cycle on bearberry and other Arctostaphylos species. Melampsorella caryophyllacearum causes the similar disease of true firs; it alternates in its life cycle to chickweeds and their relatives in Cerastium and Stellaria.

REVIEW

Spruce Broom Rust

Spruce broom rust occurs only in North America. The most concentrated outbreaks are in northern Arizona and southern Colorado on Engelmann and blue spruce and in Alaska on black and white spruce, with local epidemics scattered over the 2,000 miles between these areas. The rust is missing where Arctostaphylos does not grow, for instance in southeastern Idaho.

Spruce brooms are associated with bole deformation, loss of increment, spiketops, and mortality (Bourchier 1953; Foster and Ziller 1952; Kimmey and Stevenson 1957; Thomas 1953). Brooms also serve as infection courts for decay fungi such as Fomes pini and Lentinus lepideus, and thereby increase cull (Hedgcock 1912; Mielke and Davidson 1947). A survey in Colorado determined that heart rot was associated with 68 percent of dead rust brooms on trunks of sampled Engelmann spruce (U.S. Forest Service 1959). Wind breakage at rust trunk infections has been reported by Alexander (1957) and Pady (1942). No comprehensive study of economic effects of spruce broom rust has been made, and there has been no large-scale control work.

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[1] Plant pathologist. Data from Colorado were obtained while the writer was with the Rocky Mountain Forest and Range Experiment Station at Fort Collins, Colorado. Work was completed at headquarters in Logan, Utah, maintained in cooperation with Utah State University.

Fir Broom Rust

Melampsorella occurs in most of the world's fir forests. Only European foresters, however, have undertaken large-scale investigation and practical control of this "most important" parasite of fir (Neger 1924). In Germany Melampsorella usually infects from 2 to 15 percent and occasionally 20 to 30 percent of silver fir trunks before control work (Heck 1894; Flury 1932). Percentage of trees infected may be much higher, particularly in wet sites, if branch brooms are counted (Koch 1891; Neger 1924). Other site factors and stand composition appear not to affect the amount of rust on fir in Europe (Fröhlich 1931; Schwerdtfeger 1957).

Mortality due to snow and wind breakage at rust trunk cankers is thought to be important in Eurasia (Hartig 1900; Vanin 1955). But cull due to bole deformation and to decay centered at rust cankers is regarded as by far the most serious form of broom rust damage (Koch 1891; Schwerdtfeger 1957). Rust-caused swellings and resin accumulations make infected trunks undesirable for pulpwood. Cankers provide infection courts for decay fungi, chiefly Fomes hartigii and Pholiota adiposa (Fröhlich 1931; Gäumann 1950; Hartig 1900). In Siberia a large part of fir heart rot is associated with broom rust (Kravtsev 1933). Effects of rust brooms on tree growth rate are not thought to be important in Eurasia, and Guinier (1922) claims that even the branch on which a broom is located continues normal diameter growth.

Because fir stands in Europe are managed intensively, it has proved possible to eliminate rust cankers economically during regular thinnings (Heck 1927). Controversy regarding the pruning of branch brooms has continued for decades, but even the "broom-control" group believes that pruning prevents trunk infection and subsequent cull, not that brooms themselves cause loss (Guinier 1922; Schwerdtfeger 1957).

Fir broom rust is widespread in North America. Pomerleau (1956) reported a large outbreak in the East in balsam fir, but most concentrations of the rust are in the West. It is locally common in California on red fir, and was found on 3 percent of 917 trees of this species examined in statewide randomized plots (California Forest Pest Control Action Council 1963). Serious outbreaks on white fir occur near Albuquerque, New Mexico.[2] But the rust reaches its greatest known abundance on subalpine fir in the Sawtooth, Cache, Caribou, and Bridger National Forests of southern Idaho, northern Utah, and western Wyoming (Mielke 1957). Informal tree counts by Forest Service investigators on Idaho's Cassia Plateau indicated that 70 percent, 80 to 90 percent, and 90 to 95 percent of the subalpine fir were infected in three different localities.

Fir broom rust in North America reduces growth and eventually causes death, particularly in seedlings and saplings (Mielke 1957). Freeman (1905) and Faull (1932) also reported stunting of trees by this rust. However, Boyce (1961) stated that lightly infected firs seem to grow as rapidly as sound ones, and Meinecke (1916) thought that branch brooms in no way affect trunks. Alexander (1958) recognized the importance of trunk cankers in subalpine fir. But it appears that the ratio of trunk infections to branch infections of Melampsorella is lower in America than in Europe (Boyce 1961).

[2] Rocky Mountain Forest and Range Experiment Station, unpublished observations.

In America, unlike Europe, no large-scale projects to control fir broom rust have been undertaken--possibly because we manage fir stands less intensively and are uncertain that broom rust causes significant damage here.

CURRENT STUDIES

Spruce Broom Rust: Damage Tallies in Outbreaks

Survey strips were run through broom rust outbreaks in six National Forests in Colorado to identify any easily recognized effects that the rust might have on Engelmann spruce. Ten transects were examined in the San Juan, Rio Grande, Grand Mesa-Uncompahgre, Gunnison, White River, and San Isabel National Forests. Sampled stands were mature or overmature, and either uncut or lightly cut over. Transects were 0.5 chain wide, varied in length, and included a total of 1,249 spruce. Because surveys were deliberately placed in rust outbreak areas, the infection levels recorded are not representative for these forests. The transects began at arbitrary starting points chosen before they were reached, therefore no trees in them had been seen before tallying began. This resulted in two transects' being mostly in healthy stands. Percentages of spruce infected varied from 5 to 25 in the 10 strips; the average was 17 percent.

Rust infection appeared to be causally related to tree death in these samples. Much higher percentages of dead trees than live trees were broomed in the eight transects that included dead trees (table 1). Furthermore, the dead trees that had been infected bore an average of 2.3 brooms (or clusters of brooms) per tree, compared to 1.5 in infected live trees. Because the mortality rate was 7 percent for rust-free trees, but 23 percent for broomed trees, rust infection appeared to increase the probability of a tree's death by a factor of more than 3. It could be argued that rust "picks on" weak or dying trees and that the correlation, therefore, is not significant. But this would be contrary to facts known about infection by rust fungi, namely that the more vigorous members of a plant population are the most likely to be infected by these obligate parasites (Arthur 1929).

Table 1.--Comparison of rust broom on live and dead spruce in eight transects in Colorado

Tree size	Live trees		Dead trees		All trees	
	Total	Broomed	Total	Broomed	Total	Broomed
	Number	Percent	Number	Percent	Number	Percent
Less than 6" d.b.h.	180	5	15	13	195	6
More than 6" d.b.h.	818	18	93	48	911	21
All trees	998	16	108	44	1,106	18

Spike-topped and broken spruce were recorded separately in the 10 transects (table 2). All dead tops in small spruce apparently resulted from suppression, but in larger trees 8 of 14 spike-tops originated at rust infections. Broken trunks were not significantly correlated with rust in the samples, but trees broken at rust brooms are commonly seen in Colorado (fig. 1).

Table 2.--Occurrence of rust brooms in spike-topped and broken spruce in 10 transects in Colorado

Tree size	All live		Spike-topped		Broken	
	Total	Broomed	Total	Broomed	Total	Broomed
	Number	Percent	Number	Percent	Number	Percent
Less than 6" d.b.h.	241	5	7	0	3	33
More than 6" d.b.h.	900	17	14	57	10	20
All trees	1,141	15	21	38	13	23

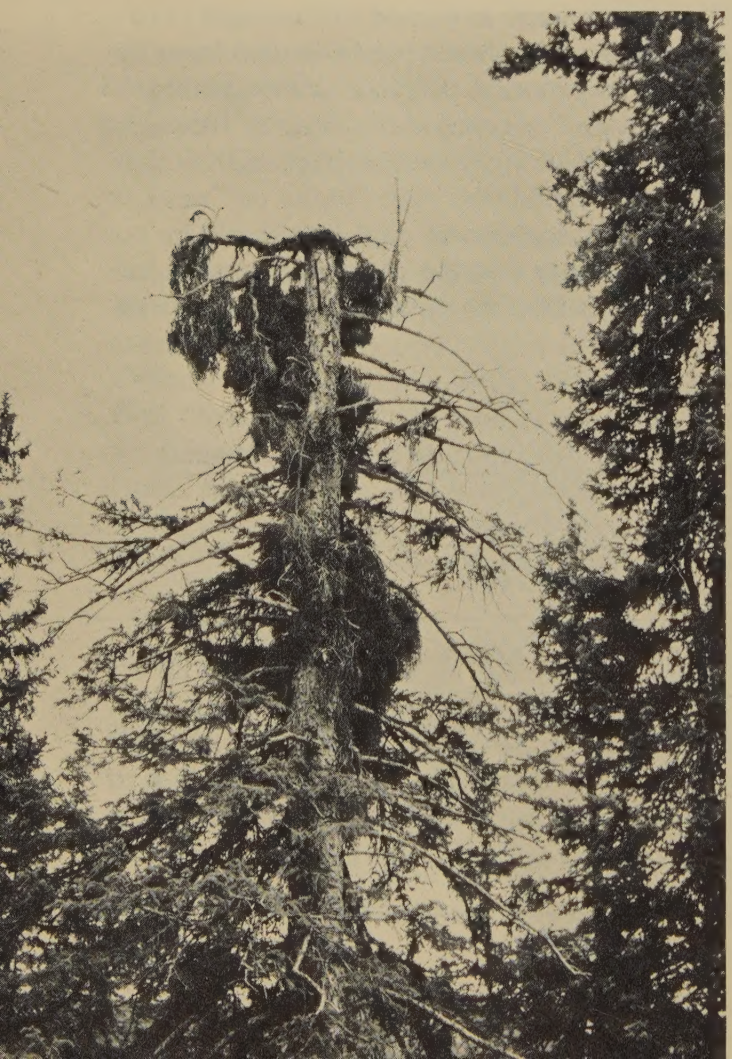

Figure 1.--Engelmann spruce in San Juan National Forest. Rust infections in trunks provide starting points for decay that makes trees susceptible to wind breakage.

Spruce Broom Rust: Study of Effects on Growth

In 1962 a small study was made to determine whether broom rust causes growth loss in Engelmann spruce. Three variable-size plots were chosen, one each in the Deerlodge (Montana), Teton (Wyoming), and Wasatch (Utah) National Forests. In each plot we marked 10 to 12 broomed spruce with an aggregate diameter of 80 inches. The trees selected were those nearest an arbitrary point in each plot. Trees that were forked or otherwise deformed, that were less than 3 inches d.b.h., or that had only one or two small brooms far out on the branches were excluded from the sample. After marking the diseased trees, which had an average of three rust brooms (or clusters of brooms) each, the rust-free tree nearest each marked tree and having a d.b.h. within 10 percent of the latter's diameter was identified. Average distance between members of diseased-nondiseased pairs was 14 yards. The paired trees were then cut and dissected to compare ages, diameter growth by decades (measured on a 6-inch stump), heights, height growth in the last 10 years, and extent of decay. Assuming that infection occurs on current-year shoots, we determined the approximate year of first infection from the age of the stem section bearing the oldest broom. Diameter growth rates before and after the decade in which first infection occurred were compared for infected and healthy trees. In almost all trees, rusted or not, annual increments increased with tree age, because the trees had been partly suppressed in their early years.

Table 3 summarizes data from the three plots. The difference in recent height growth correlated with rust infection is real, by "t" test, unless a 1-in-100 mischance has occurred in sampling. Measured diameter growth differences also reflect actual effects of rust unless a 1-in-17 mischance occurred in sample selection. Current height and diameter growth were greater in healthy trees than in broomed trees in all three plots, but the percentage differences averaged twice as large in the Teton plot as in either of the others. In the Teton plot infections averaged only 1.4 per broomed tree, compared with 3.3 and 3.6 in the other plots; but the average time since infection was 61 years, compared with 20 and 30 in the others. Time since infection thus appears more important than number of infections in evaluating damage.

Table 3.--Average measurements of 32 pairs of healthy and rust-broomed Engelmann spruce

Item	Healthy trees	Broomed trees	Percentage difference
Diameter at breast height	8.66 in.	8.63 in.	-0.3
Total age	126 yrs.	127 yrs.	+1
Total height	49.5 ft.	49.2 ft.	-1
Height growth, last decade	6.0 ft.	4.5 ft.	-25
Diameter growth before decade of first rust	1.6 mm./yr.	1.9 mm./yr.	+19
Diameter growth after decade of first rust	2.9 mm./yr.	2.3 mm./yr.	-21

The broomed trees, on the whole, had more potential for growth than did the healthy trees, as is shown by their faster growth before infection by rust. Therefore their final diameter increments would have averaged more than the 2.9 mm. per year given for healthy trees in table 3, if they had not been infected. We can assume that the increase in growth rate of the broomed trees would at least have equaled the 1.3 mm. per year of the healthy trees; this increase would give the broomed trees an expected rate of 3.2 mm. per year (1.9+1.3 = 3.2) in the broomed trees. Or we can assume that the growth increase would be proportional to initial growth rates, for an expected rate of 3.4 mm. per year in the broomed trees (1.6/1.9 = 2.9/3.4). On the basis of these assumptions the apparent reduction in diameter growth caused by rust is 28 percent or 32 percent, respectively, rather than the 21 percent given in table 3.

Decay associated with rust brooms in the sample was of minor importance. There were 25 trunk infections by the rust, only 2 of which appeared to be the centers of decay. The decay columns were small.

Fir Broom Rust: Study of Effects on Growth

To measure effects of Melampsorella on fir, we made comparisons of growth of paired healthy and infected trees by the methods described above for spruce broom rust. Plots were in the Sawtooth (Idaho), Cache (Idaho), and Wasatch (Utah) National Forests. Average distance between members of pairs was 39 yards. The 33 broomed trees of the sample bore an average of 9 rust brooms each.

From the data of the three plots summarized in table 4, no statistically significant differences in growth between healthy and diseased trees are evident. This absence of growth effects may result from the relative recency of infection. Of the 300 fir brooms examined, fewer than 10 were more than 30 years old; average age was 19 years. Perhaps the apparent difference in recent height growth between healthy and rusted trees (table 4) represents the first damaging effect of rust.

Table 4.--Average measurements of 33 pairs of healthy and rust-broomed subalpine fir

Item	Healthy trees	Broomed trees	Percentage difference
Diameter at breast height	7.61 in.	7.58 in.	-0.4
Age	100 yrs.	100 yrs.	0
Height	43.6 ft.	41.4 ft.	-5
Height growth, last decade	6.5 ft.	5.8 ft.	-11
Diameter growth before decade of first rust	1.8 mm./yr.	1.8 mm./yr.	0
Diameter growth after decade of first rust	2.6 mm./yr.	2.6 mm./yr.	0

Figure 2. --Dead subalpine fir in Sawtooth National Forest. The death of such a tree, bearing more than 100 rust brooms but showing no other apparent symptoms, suggests that broom rust infection can kill directly.

Figure 3. --Subalpine fir, Sawtooth National Forest. Trees dead above rust trunk infections are common.

Although this study did not demonstrate that branch brooms cause measurable effects, one cannot argue from this that Melampsorella causes no damage in the Rocky Mountains. The study specifically excluded the broomed firs most affected by the parasite--the dead, spike-topped, and small deformed trees (figs. 2 and 3). Their frequency and significance have not been evaluated.

In the fir sample, as in the spruce, decay associated with rust was of minor importance. Of 300 infections in the sample, 29 appeared to extend into trunks, and only 1 of these appeared to be a center of decay.

SUGGESTED STUDIES

These pilot studies suggest both additional questions and some changes in technique. It appeared that time since infection bears importantly on damage, but that random samples of infected trees do not give a comprehensive sample of ages of infection. To evaluate future effects of broom rust on fir growth in the Intermountain Region we should find examples of outbreaks 50 to 100 years old. This will require a radical departure from random sampling; as yet no outbreaks of fir broom rust more than 26 years old have been encountered in the Region. It will also be possible, in a larger sample, to determine the relation between intensity of brooming (percentage of crown broomed) and growth decline.

Another unknown to be studied is how broom rusts kill trees. Among the possible explanations are (1) food loss to the parasite and to the hyperactive brooms, (2) interference with conduction, and (3) increase in secondary pests following rust infection. Whether bark beetles single out rusted trees for attack, as several foresters have suggested, is a particularly important problem.

The work reported in this paper does not completely answer its starting question, "How significant is broom rust damage?" Our studies show damaging effects of rust on spruce, and suggest that similar effects might be expected in fir outbreaks older than those sampled. Further work will be required to evaluate breakage and mortality due to rust and to measure damage to young trees.

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Yellow witches'-brooms caused by rust fungi are associated with several kinds of damage to spruce and true fir. In sample plots in the Rocky Mountains, occurrence of spruce broom rust correlated significantly with mortality and with declines of more than 20 percent in diameter and height growth rates in infected trees. Fir broom rust appeared to have little effect on growth rates, perhaps because sampled infections were young.

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